



## Short range wireless technologies: Why, when and how to apply them

Over the last decade, the cost of short range wireless transmitters has decreased immensely. This makes it possible to implement wireless features in all sorts of products and devices for both professional and domestic use. All of a sudden, designers and producers of these devices find themselves faced with an entirely new set of challenges, regardless of whether or not they choose a proprietary solution or decide to go for one of the many ready-to-go wireless solutions. A common experience is that the development cost as well as the support cost is considerably larger than expected, even for experienced companies. The reason for this is often the complexity involved when integrating wireless application into a complex electronic device. This requires a high level of skills in both radio transmission and electronics.

As a consultancy and testing centre, it was natural for DELTA to build competences within short range wireless technologies from the very start. This means that we have already gathered considerable experience in supporting our customers' product development process, also when it comes to wireless features. Also, we have a unique expertise in testing the wireless products, to make sure that they meet regulatory demands.

In this paper, we have collected the cream of our experience, which we believe will be of help to companies engaged in wireless product development:

Part I: Companies are not skilled enough in wireless technology. The fact that 95% of products fail their first test indicates that more skills and knowledge are required.

Part II: To be or not to be ... wireless? A short guide of how to determine whether or not to make a product wireless.

Part III: The ABC of wireless product development - how do you actually do it?

Part IV: DELTA helps OJ Electronics to develop wireless technology to regulate underfloor heating – a world first.

We hope you will benefit from reading this paper. We are happy to answer your questions related to this paper or simply to discuss any challenges regarding wireless product development that you might be facing. Please contact us by mail or phone, see details below.

### **Part I: Companies not skilled enough in wireless technology**

95 % of all wireless products fail the first time they are tested. Far too many companies do not take development work seriously enough and end up going back to the drawing board.

Wireless technologies are the future. This is why a large number of companies would love to have wireless products on their shelves. Even companies that have not previously worked with this kind of technology. Many companies, therefore, are faced with working with technologies that are entirely new to them. This involves many challenges, of course, and at DELTA we know that there is plenty of room for improvement when it comes to wireless product development. We can say this with a certain amount of confidence, based on figures from our collaboration with a large number of companies that develop wireless technologies.

### **95% of all wireless projects fail first test**

In recent years, DELTA has operated an advice centre for wireless product solutions, partly funded by The Danish Council for Research and Innovation's performance contract

funds. The aim is to help companies achieve success with wireless technology in their products. However, in our experience it is not always easy to obtain permission to advise development personnel and company management on wireless technology. Unfortunately, we might add, figures show that there is a need for companies to pay more attention to this area: 95 % of all wireless projects do not pass the required testing at the first attempt and 75 % of projects continue to struggle with unresolved problems after failing this first test. A much too high failure rate!

### **External advice – waste of time?**

Typically, however, companies are not interested in support at the crucial early stages of the development process. External advice is seen as an unnecessary and expensive solution, for which they have no use. Ironically enough, it is precisely this point of view that can make things expensive. We have encountered far too many companies that have wasted time and resources on failed and delayed development processes. This is all the more irritating as experience also shows that the worst risks can actually be avoided by listening to and learning from others who have been through a similar process. Neither should you believe that it is only small, inexperienced companies that run into problems with their wireless challenges. DELTA has worked with all kinds of companies: from start-up sole traders to some of Denmark's largest companies with the greatest resources.

### **Know requirements from the start**

The following process is quite common: the company fully develops the product before identifying the requirements that the product must meet. Then they have to "rewind" to adjust the product so that it meets the requirements, which means that most projects experience significant delays. Far too few development projects use design review and pre-test early in the process – measures that could prevent many problems later. Almost half of the companies we have had contact with either abandon the fully developed product or do not comply with the formal requirements, when marketing the product.

### **Risk of prolonging time-to-market**

Overestimation of their own abilities and underestimation of the formal requirements. This is a somewhat provocative summation of the causes of failed development projects. If you have decided in advance that a new wireless product must be a success, it is easy to have a kind of tunnel vision about the rest of the process. You can have your blinkers on and ignore, trivialise or simply overlook basic problems along

the way. The result is predictable, as the figures show. In the worst case scenario, the company's very existence can come under threat if the product does not go to market on time or at all. In any case, it represents a waste of resources and a high price to pay for the experience.

### **Good wireless development practice**

Fortunately, it is possible to draw up some guidelines for a good wireless development project. DELTA has developed "The ABC of wireless product development", which provides a brief introduction and checklist for the most important problems: the idea stage, requirements specification, testing and test requirements, physical and legal parameters, skills identification, design, implementation, approval, production and launch. In short, all the stages and problems that you need to go through in wireless product development. As wireless technologies are becoming increasingly more widespread, it is even more important that wireless technologies comply with standards and other formal requirements. The more the air becomes filled with radio waves, the greater the risk of "noise" in wireless communication if standards and regulatory requirements are not adhered to.

### **Make optimum use of knowledge and resources**

Companies that want to develop wireless technology must take their task seriously. Do you have adequate knowledge? Do your employees have the necessary skills? Do you have the equipment and technology for the job? Do you have the time and resources to do it properly? Many companies answer yes to these questions, but the results of their efforts all too often show that they have not answered correctly. Wishful thinking has proved stronger than their sense of reality. In the first instance it is the company itself that pays the price, but the high failure rate is also a problem for Denmark's competitiveness. At a time of financial crisis, like the one we are currently experiencing, there is a particular need to make optimum use of knowledge and resources.

### **Part II:**

#### **To be or not to be ... wireless?**

A short guide of how to determine whether or not to make a product wireless

Should we make our product wireless? For many companies, this is a pressing question, for which there is no easy answer. Making a product wireless can mean a world of difference. It can result in redefining the type of company you are and in opening up new markets. It goes without saying that this

relies on the utility value of the product increasing if it is made wireless. In this article, we try to help by describing the factors that determine whether a product is suitable for wireless communication.

## Summary

In order to determine whether a product is suitable to be made wireless, you need to assess the following factors:

- Cost of installation and materials
- Convenience of use
- Data capture
- Expansion to Web and M2M
- Mobility
- Branding
- Competitors and market share
- Time-critical communication
- Vital communication
- Compatibility and communication with other devices
- Water and electricity consumption
- Security benefits

## Installation and materials

The first thing you should do when considering wireless communication is to see what it will save (or cost) in the production price per unit compared with the current product. If you have large costs associated with laying cables, using wireless modules instead can be an advantage. If, on the other hand, you have data-heavy transmissions, it can be expensive to exchange them for wireless modules as this places great demands on the technology and the components.

## Convenience and added value

One of the most common reasons for making products wireless is that it improves the product's convenience of use. The ability to control a window remotely, for example, will increase convenience and means that the customer will be prepared to pay more for the end product. On the other hand, there is probably no advantage to making a toilet flush wireless, as the function requires that a person has been in the immediate vicinity of the product in any case.

## Web, M2M and data capture

You should examine the possibility of developing multiple applications that can be sold as additional services. Could you create a Web service that customers can subscribe to which closes their windows when it rains? Or could the customer themselves be able to control whether a window is open

or closed from their mobile phone? Once you do have such data available, you can start data capture. This data could be very valuable for other businesses and the authorities. It is easy to imagine that a thermostat manufacturer would pay to know when the window is open so that their thermostat could automatically turn off the heating – in other words, intelligence using M2M (Machine to Machine) communication. This additional functionality represents a direct increase in the value of the thermostat and will therefore be worth money to its manufacturer.

## Mobility

Making a product mobile is also a key parameter. It is important here to rack your brains and assess whether this is actually possible. There are many factors that can have a major bearing on this: weight is an obvious limitation, but electricity and water consumption must also be taken into account. These can of course be reduced, but the challenge of doing so may be almost impossible.

## Branding, competitors and market share

You should consider whether a technology brand gives added value to the product. Take an MP3 player, for example. Do you buy the one with the Bluetooth logo on the front or the one without? Gradually, as more and more people begin to gain awareness, confidence and trust in a brand, it can provide added value. At the same time, you need to keep an eye on your competitors. If they all install wireless technologies in their products, you will see your sales fall over the next few years if you do not follow suit.

## Vital communication

In terms of radio communication, there are a few things that you need to consider. Is data communication time-critical? For example, does data need to be received as soon as it has been sent? If you manufacture joysticks for computers, it is obviously not so much fun if the communication link has a 200 ms reaction time, as this will result in a slow joystick. This is not impossible to overcome, but presents a number of demands at the development stage. Is the communication a matter of life-or-death? Sadly, there are many examples of the wireless link failing where this has not been taken into account at the development stage. If your communication is vital to life, you must take several precautions with regard to wireless communication, and it is almost certain that one system will not be enough.

## Part III:

### The ABC of wireless product development

The decision to make your product wireless has been made.

What remains now are the many questions of how to actually do it.

Wireless technology is not a new phenomenon. It is a more than a century ago Marconi developed the first radio, and a lot has happened since then.

Today, short-range wireless modules and chips, such as Bluetooth, have become so mature and cheap that it may be profitable and even necessary to incorporate them into a wide range of products that have traditionally not contained wireless units. As a result, manufacturers and developers of devices are currently facing a whole range of new tasks and challenges in relation to their traditional products.

These tasks and challenges appear at all stages of the product development process, and identifying and dealing with potential problems before they arise can be vital to a successful development process.

This article is a collection of DELTA's experience in relation to actual customer projects, and so provides a range of hints and practical advice for those of you who in are the process of making your products wireless, but who have only very little or no experience with wireless technology.

### Ideas and requirements

Is the product suitable? Do we have the necessary skills? Physical and legal parameters. A good requirements specification is becoming increasingly important.

Every new product or development of an existing product starts with an idea. Making a product wireless can provide major benefits and new opportunities, but not all types of products are suited to going wireless and developing a wireless product can be expensive and time-consuming.

A wireless solution can never provide the same reliability as a wired one. Wireless communication is more vulnerable to various kinds of interference, for example, and a wireless device is often dependent on battery power.

If it is vital that the product you intend to develop has a reliable connection, wireless is not really the way to go. However, if you can live with losing connection now and again, the

possibilities that wireless technology opens up can be well worth it.

You should also be prepared for longer development times and higher costs for wireless products than you are used to. Often, companies do not have staff with the right skills, so it is worth noting that you may need to

- help existing employees acquire the necessary skills
- employ new staff who already have the right skills
- outsource tasks to subcontractors.

However, all these options cost time and money. Which solution (or combination of solutions) you choose should be based on how much control you want over the design, how many future projects involving wireless technology you anticipate, and what level of service you want to provide to your customers.

It is also important to check whether it is possible to complete the task within the given parameters. Finance and time are, of course, parameters that need to be taken into account, but physical and legal parameters are of at least equal importance.

Legal parameters stipulate what frequency, bandwidth, signal strength, duty cycle, etc. you can use for a particular purpose. If you do not investigate and identify which legal requirements apply to a product, you risk developing something that you will not be allowed to sell.

The physical parameters determine the range, data rate, battery life, etc. that you are able to achieve within the legal parameters. If you do not take into account the physical parameters, you risk developing a product that does not meet the user's requirements and is therefore unsaleable.

In addition to the above, the needs of industry in the form of functional requirements for the use of certain technologies may be of importance and you should consider the requirements for reliability, functionality and interoperability that customers, end users and you yourself have.

It is important to ensure that you identify all the requirements and describe how the fulfilment of these is to be demonstrated through verification, testing, documentation and labelling. The requirements specification should address all the relevant requirements for the product, the system and the individual components.

As well as a satisfactory requirements specification, it can be a good idea in some cases to make a prototype (for example, using development kits) to test whether you can make the ends meet in a concept or idea. It is usually relatively quick and cheap to develop a prototype that you can use to test whether you can achieve the desired data rate or range, for example.

## Design

Develop yourself or buy finished modules? Remember to incorporate testing requirements at this stage!

The first, and in some cases most difficult, question you need to ask yourself at the initial design stage is how much work you want to do yourself as opposed to buying partial solutions. Today your options stretch from buying complete radio modules, ensuring a minimum of development work, to taking the plunge and writing your own protocol and designing your own radio, as well as the necessary interfaces. The choice should be made on the basis of a detailed review of all the relevant parameters identified at the idea and requirements stage.

For some types of products you will be able to find finished modules that fit the requirements specification perfectly. Other types of products may have requirements that cannot be directly met by the available modules. Typical examples are size, battery life, protocol and industry requirements for using the module.

An often-used compromise is to buy a finished radio chip, with an integrated microcontroller if required, and then to build your own stack and application on top of this existing MAC/PHY layer.

A typical problem you may encounter is that a module is not just a module. There are many definitions of what a module is, what a qualified module is (industry requirements) and what an approved module is (legal requirements). It is important here to have a good dialogue with the supplier, in particular with regard to legal requirements, as it is the end manufacturer who is responsible for compliance with legal requirements.

If you are designing both the radio element and the software element, you can avoid a lot of problems by taking into account the parameters to be tested from the very beginning. It is often the case that a manufacturer develops a product which to all appearances works perfectly on the developer's

desk, but when it comes out into the real world, or to the laboratory for testing, it simply doesn't work at all.

The ability to read and log key parameters is an important tool in a troubleshooting situation. If you are only able to confirm that there is no access, the faulty mechanism is almost impossible to identify, particularly if there are a number of faults. It is extremely useful to be able to confirm why the product is losing connection and why it is unable to re-establish the connection properly, for example.

It is also a good idea to go to the laboratory as early as possible in order to identify possible problem areas, while it is still easy to incorporate corrections into the design. Measuring emission, transmission power or sensitivity, for example, at an early stage in the development process can identify potential critical faults.

As important as it is to be able to identify problems in the design, it is just as important to include the ability to implement modifications in the initial prototype.

With regard to hardware, providing a little extra room for adding filters and impedance matching modules is a good idea. In that way you don't have to completely redesign the product, before you are able to move on and identify the next problem. Similarly, allowing a little room for an SMA connector at key positions in the RF chain, for example, can enable you to confirm which link in the chain is not working as expected.

With regard to software, it is rarely a problem nowadays to incorporate corrections, although this can be a problem in itself. It is essential to retain version control of the software you are working with, and each time you make a correction, it is important to consider any unintentional consequences this may have. There is nothing more annoying than working to solve a problem and subsequently finding out that you have been working on the wrong version of the software.

The interaction between the software and the RF development engineer can be of vital importance. A radio is a complex item, and the consequences of even minor corrections are not always obvious.

## Implementation

Even minor corrections can have serious consequences for the functioning of the product.

When you are developing a product and its components, it is important to take into account the fact that even minor corrections or adjustments can have serious consequences. Any adjustment you make, from tolerances for the dimensions of the paths on the circuit board to the kind of transistor, capacitor or coil you use, can have fatal consequences for a well-designed product. It is therefore important to have a good relationship with the subcontractors you use, whether they are internal or external. It is important that the purchasing department does not simply swap a component for a cheaper one, and it is also important that the component supplier notifies you of any changes.

Examples of the above problems are:

- detuning the antenna when attaching labels
- filters that do not work as intended when a different kind of capacitor is used
- thresholds for spurious emission being exceeded when a different kind of transistor is used

and other similar phenomena, where the effect on the product of any changes that you make is not necessarily obvious.

## Testing

Update the requirements and test specification. Start testing early in the process in order to identify problems at an early stage.

The biggest problem at the testing stage is usually time pressure. The sales people can see that the first products are ready and are just waiting to start selling, but the truth is that the testing stage is important and it takes time. If you do not document that you are meeting the relevant statutory requirements before you begin marketing, you may be risking large fines. However, it is just as important to appreciate that if you supply anything other than a good quality product to the end user, a lack of customer satisfaction will make it difficult for you to sell future products and your costs for service and complaints may become so high that you erode the financial gain on the product.

In order to meet the need to quickly take a high quality product to market, it is a good idea to start testing as early as possible. If you start testing as early as the prototype stage, you will be able to identify problems while they can still be dealt with. If you use subcontractors for components or modules, it is important to specify the tests that they should perform and what the success criteria are before asking them

to get started. It is important to review the documentation they provide in order to verify that the relevant tests have been carried out correctly, and that the results are satisfactory.

The requirements and test specification is often lacking or non-existent. It certainly should have been drawn up at the earlier product development stages, but it has not been, partly because it is not necessarily the thing you are most focused on when you have an idea for a new product, and partly because you can become a lot wiser as you go through the product development process. It is therefore a good idea to examine whether you have satisfied all the relevant requirements and described them adequately when you reach the test stage.

As previously mentioned, the requirements come from all sides. A radio product must fulfil certain statutory requirements for testing, documentation, labelling and in some cases certification in each individual country in which it is sold. Other examples of product requirements are reliability (user and manufacturer requirement), user-friendliness, functional parameters and interoperability.

You must examine each product thoroughly and critically on its own merits. There are no general guidelines when it comes to the requirements specification, which makes experience and expertise valuable at the test stage. If you have a person who has been involved in testing previous products, it can certainly be worth a little organisational reshuffle to get their input. Also, while you are actually testing the product, it is important to ensure that your findings (whether good or bad) are channelled back into the organisation, so that everyone can learn from them.

## Production and launch

Do the user manual and documentation meet statutory requirements? Changing components may require the product to be retested and re-approved.

Once you have put the initial prototypes through the testing process, you are faced with the challenges of mass production. You should consider which parameters you want to monitor in production checks, and how you want to do this. There are no guarantees in this world, and a bad batch resulting from a fault in production can have major consequences both in terms of user satisfaction as well as the potential risk of being subject to market controls from the authorities.

Another thing worth mentioning is the user manual and the documentation that accompany the product. Here you should ensure that you meet the statutory requirements in terms of what they contain and how they are written.

Once you have got production up and running and sales of the product are naturally exceeding all expectations, it is normal to start thinking about streamlining and reducing costs. You should think carefully about which components you want to replace and which you want to retain in the process. In some cases, the changes that you introduce will be significant enough that you will be required to retest the product and have it re-approved. However, a lot of money can be saved by switching to a specially developed ASIC instead of the more traditional component design, for instance. And at the same time, you can conveniently examine whether there is good reason to introduce new functionality and new features in the product.

#### **Part IV:**

#### **New wireless underfloor heating – DELTA creates a world first**

DELTA has helped OJ Electronics to develop wireless technology to regulate underfloor heating – a world first that is now ready for marketing.

You can get cold feet about wireless technology. Quite literally. When OJ Electronics decided to develop a new wireless technology to control underfloor heating, a concept was recommended to them by one of their regular suppliers. However, the solution proved unsuitable, and so OJ hunted high and low for exactly the right solution that would ensure that the new system could be launched.

#### **Initial tests showed failures**

“Initial tests showed intermittent failures, which had fatal consequences for our launch schedule. It appeared that we were a long way from the finished product, which we otherwise believed was almost ready for marketing. So we decided to ask DELTA for help. We know DELTA as serious, skilled people from other contexts, including the field of EMC, so we believed that they would be able to help us,” says Per Boysen, Project Manager at OJ Electronics. The company is a leader in the field of underfloor heating controllers, which together with HVAC controllers constitute their core business.

#### **Wireless temperature measurements – the way forward**

Instead of moulding the temperature sensor into the floor, you can use the new wireless technology from OJ Electronics to install infrared temperature sensors around the room you want to heat.

“Wireless temperature measurement provides a whole new level of flexibility, including the ability to measure at multiple points and so obtain a more accurate temperature reading, as the temperature is measured where it is most important – on the surface of the floor. Using wireless sensors, you can measure up to one and a half metres in height above the floor, and you can place them exactly where you want to measure the temperature. We believe that this is the way forward for electronic underfloor heating,” says Per Boysen.

#### **Radio transmitter with built-in-fault**

However, in order to make the technology work, the temperature sensors must be able to communicate with the thermostat and this is where OJ Electronics ran into difficulty. The thermostat was not receiving the signals from the temperature sensors and the problem seemed to occur at multiple locations. The antenna had to be changed, the receiver circuit had to be replaced, the entry filter had to be changed, and the PCB layout was redefined.

“DELTA tested the unit and discovered that the first radio transmitter we selected simply had a built-in fault. A fault that the manufacturer was probably not even aware of. DELTA provided input on adjusting the antenna, the PCB layout and the entry filter, and OJ concentrated on an alternative receiver circuit,” says Per Boysen.

An important selling point for the newly developed system is not least that it can be connected to existing underfloor heating systems – whether developed by OJ Electronics or a competitor – so you can also enjoy the benefit of wireless technology in older systems that have built-in temperature sensors. This is a major benefit for renovation projects, as it means you do not need to pull the floor up.

#### **Wireless more complex than expected**

At the start of collaboration, DELTA produced a report identifying the areas of the technology that could be the cause of the problems. There were 16 items in total.

“Wireless proved to be a lot more complex than we ex-

pected. There are so many things you need to take into account: PCB, noise signals, antennas, assembly tolerances, filter inputs, and many other things that can cause problems, either individually or together,” says Per Boysen. Together with DELTA, OJ Electronics has reviewed all the elements of the chosen technology and has optimised the antenna among other things.

Once the new wireless thermostat system was fully developed, DELTA took care of obtaining approval for the technology from UL International DEMKO, which is the certifying authority for the new wireless thermostat. DELTA drew up an accredited test report, which formed the basis of approval. Subsequently OJ Electronics is able to market the new system on its key markets.

### **Experts in wireless technology**

“DELTA has the expertise and they also have the equipment to carry out testing. They have staff who only work on wireless technologies, and they therefore have significant expertise in this field. Eventhough we are a very innovation-driven company with 30 people in our development department, we are not experts in wireless technology to the same level as DELTA. But we have found DELTA to be good at passing on their knowledge to us and thereby increasing our knowledge,” says Per Boysen, who also stresses that DELTA is completely independent of supplier and can therefore impartially advise on the best solution, without taking a particular commercial interest.

“Of course, DELTA's advice isn't free, but we are currently investing in wireless technology and we therefore consider support from an external expert in wireless technologies to be part of the development costs. Next time we will probably not need to pay for quite so many hours as we learn something new every time. However, we also know that wireless is an area of technology that is constantly changing. Almost every day we see new technologies and opportunities and as a company you have to consider how many of your resources you want to use every day on keeping up with the development of these specialist technologies. In this case, we decided to acquire some expert support from DELTA, who always keeps up-to-date with the latest wireless technology. We did this because we decided that we did not want to use the resources here at OJ Electronics to become experts in wireless technology, at least not to the same level as DELTA,” says Per Boysen.

### **Continued collaboration with DELTA**

At OJ Electronics, the future holds a number of products that use wireless technologies, and that is why they have decided to continue their collaboration with DELTA.

“Wireless technologies fit in well with our strategy of entering the building management market. That is why we will be using DELTA in the future, so that they will become a sparring partner at a very early point in the development process. The later in the development process that you find a fault that needs to be corrected, the more expensive it is the more resources you have to waste, and the later you are able to take the product to market. This is what we aim to avoid by having DELTA on board from the start. If we had not involved them, we would probably still be trying to solve the problems, whereas now we are ready to market a world first,” says Per Boysen.

### **About OJ Electronics**

OJ Electronics has three business areas: controllers and frequency converters for HVAC systems, controllers for hydronic underfloor heating systems, and thermostats for electrical underfloor heating systems. OJ Electronics has its head office in Sønderborg, Denmark, with a staff of 170. They have sales offices in the UK, the USA and Poland. 97 per cent of OJ Electronics' total production is exported. Read more at [www.oj.dk](http://www.oj.dk).